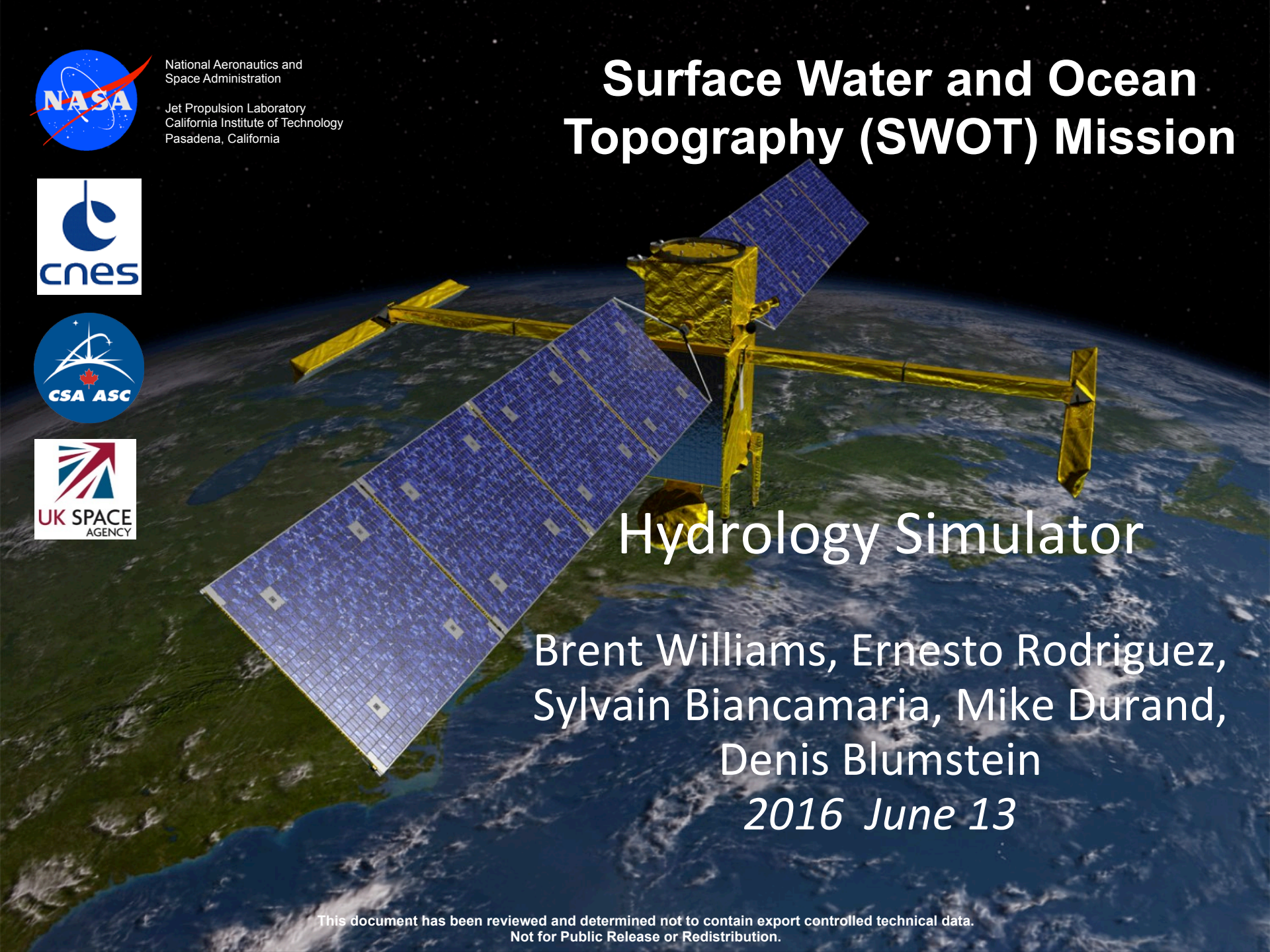


National Aeronautics and Space Administration

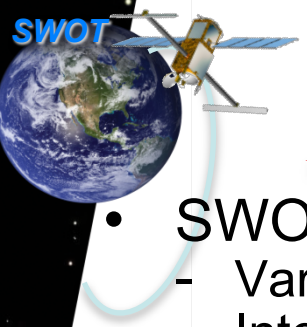
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Surface Water and Ocean Topography (SWOT) Mission

Hydrology Simulator

Brent Williams, Ernesto Rodriguez, Sylvain Biancamaria, Mike Durand, Denis Blumstein

2016 June 13



Simulator Overview

- SWOT Hydrology Simulator is modular
  - Various simulator modules and prototype code/algorithm implementations
  - Interfaces at various product levels (interferogram, water-mask, pixel cloud, vector product)
  - A bit of a learning curve to come up to speed

- SWOT Hydrology Simulator (JPL)
  - Generates radar interferograms, detects water (pixel-wise detection), and geolocates to a pixel cloud
- RiverObs (JPL)
  - Takes in the pixel cloud output from SWOT Hydrology Simulator makes estimates of key river parameters over sub-reaches (width, height , slope)
- Other modules and simulator implementations
  - Vegetation module (CNES/LEGOS)
    - ♦ Awaiting processing of AirSWOT near nadir channel data for validation
  - Large-scale SWOT pixel-cloud simulator (CNES/LEGOS)

- Currently no modules for lake vector products, or raster-like (wetland) products distributed as part of hydrology simulator
  - Experimental prototype code exists but it has not been the highest priority to produce algorithms and modules for distribution

SWOT Hydrology Simulator (JPL)

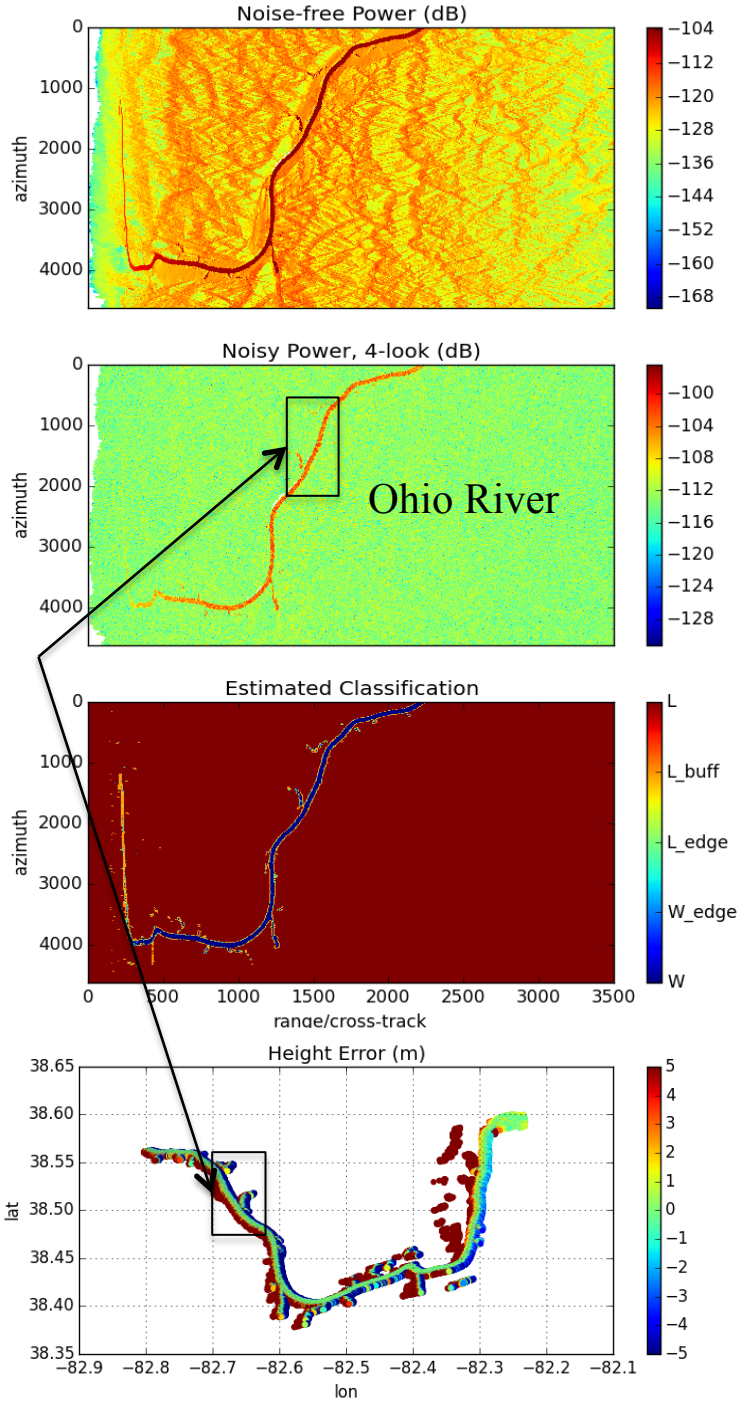
Simulates data and processing from radar interferograms to the geolocated pixel cloud

Distributed target simulator

- Directly generates interferograms with appropriate statistics for SWOT geometry

- Implements
  - Interferogram generation considering
    - ♦ Presumming
    - ♦ Coherence-time azimuth smearing of water
    - ♦ Noise addition considering coherent gain power
  - Multilooking (simple and adaptive)
  - Water detection
    - ♦ Pixel-wise Bayes detection with clean-up filter
    - ♦ Pixel-wise fractional water estimation
  - Geolocation to pixel cloud

Zoomed area in following slide

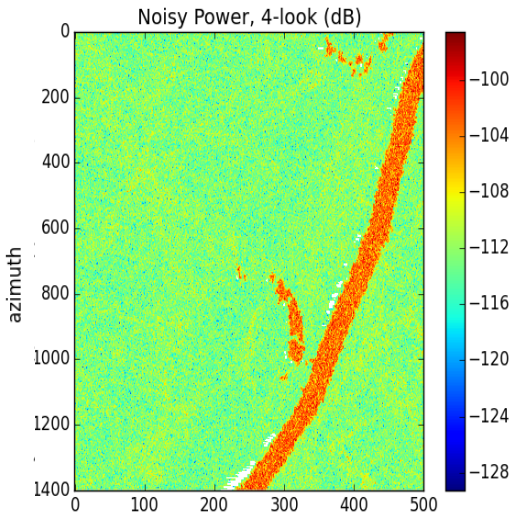


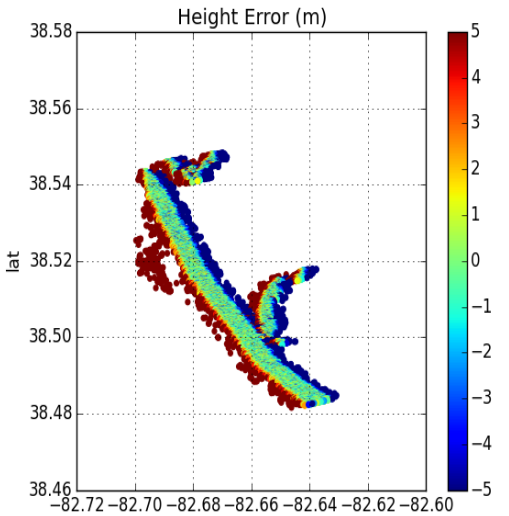
SWOT Hydrology Simulator (JPL)

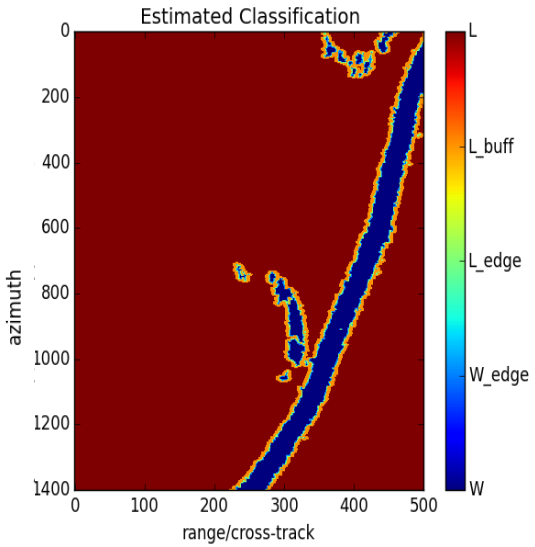
Inputs needed

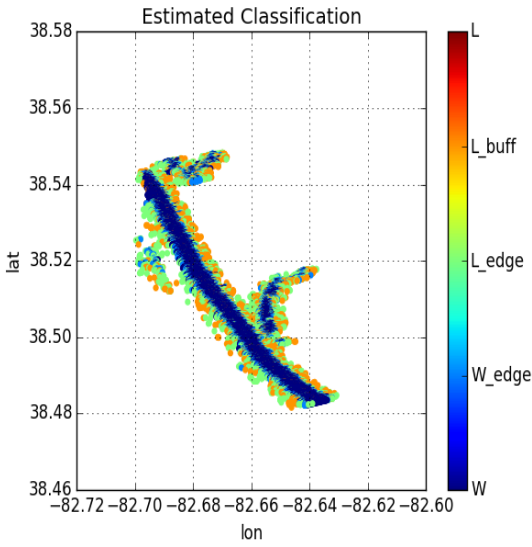
- GDEM DEM=DEM with water mask
- Lat/lon region to process
- SWOT Orbits (distributed with software)

- Update soon to be distributed with
  - Updated orbits (including fast sampling phase)
  - Algorithm improvements
  - Improvements to simulating geophysical uncertainties (e.g. dark water)
  - Pixel-cloud product prototype with multiple smoothing layers (e.g., rare, med, well-done)

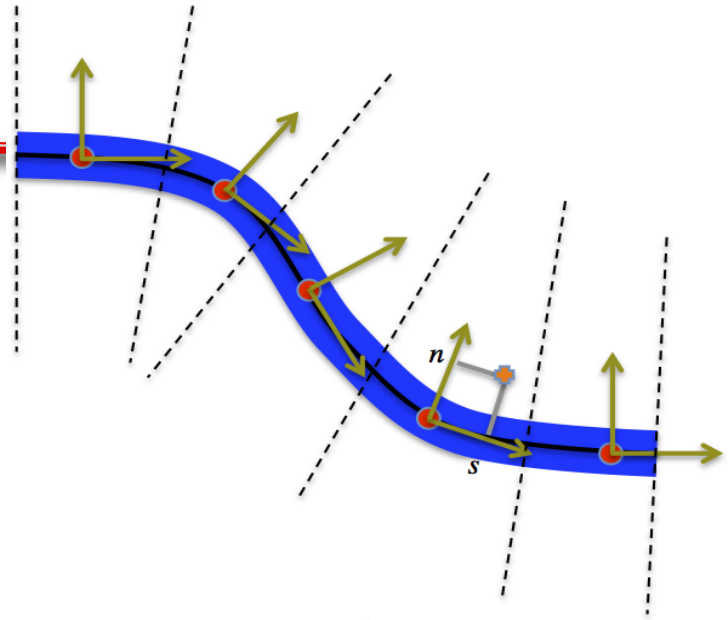








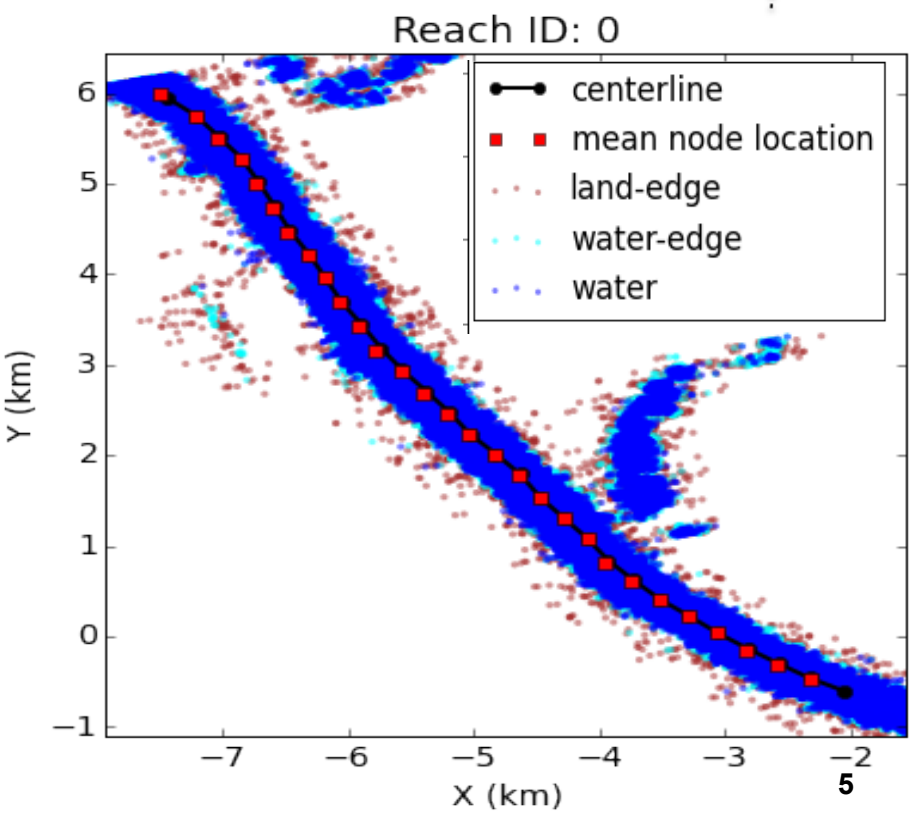
RiverObs



Takes pixel cloud and estimates quantities over sub-reaches (nodes)

Uses center-line and reach definitions from prior database

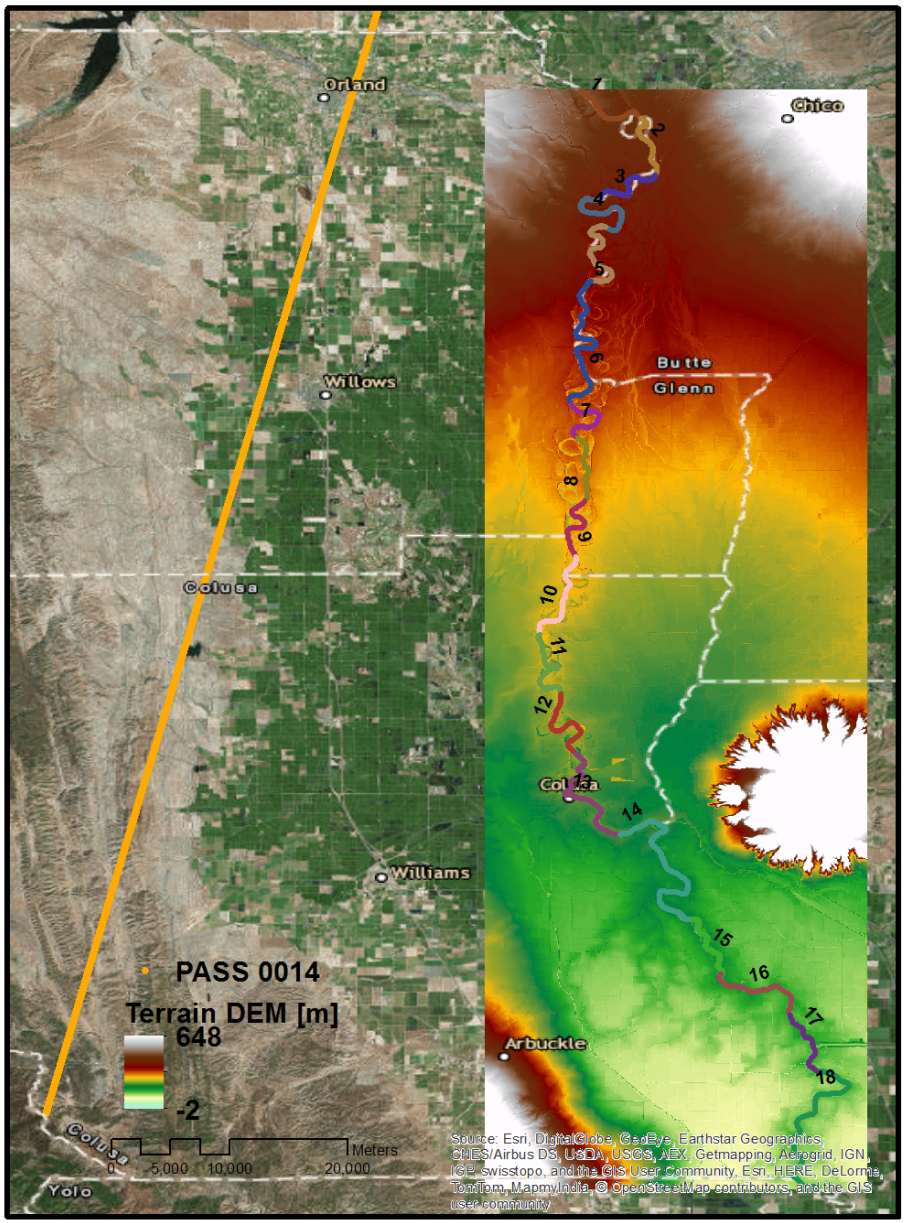
- Center-line and nodes
  - Associates pixels to closest node (exclude those beyond some threshold)
  - Assigns an along-river and cross-river coordinate
  - Computes node-level metrics: width and height
    - Width estimated 3 different ways
      - Based on total pixel area (more robust to geolocation errors)
      - Based on STD around centerline
      - Based on maximum distance (Peak-to-peak)
  - Estimates reach slope using nodes
- Outputs reach-level vector product
  - Reach length, slope, avg. height
  - Center-line location (mean node coordinates)
  - Other useful quantities (viewing geometry, inundated area…)



ADT Uses of Hydrology Simulator

- Developing, refining, and tuning algorithms
  - Classification/flagging (layover)
    - ♦ Performance with respect science requirements
      - ○ Swath average area % error and height error at reach/water-body level of aggregation
    - ♦ Simulate scenes of lakes and rivers at different places in swath, various σ_0 contrast, coherence time smearing etc.
  - Multilooking
  - Phase unwrapping, geolocation with imperfect DEMs
  - River reach aggregation (RiverObs)
  - Lake/resevoir aggregation (possibly polygon extraction)
  - Discharge algorithms
- Refining product definitions
  - Pixel Cloud
    - ♦ Data layers
    - ♦ Averaging scales
  - Pass- and cycle-based vector products
    - ♦ Start from pixel cloud
    - ♦ Explore various methods of aggregating pixels into river reaches, or lake areas/shapes
  - Wetland and raster-like products

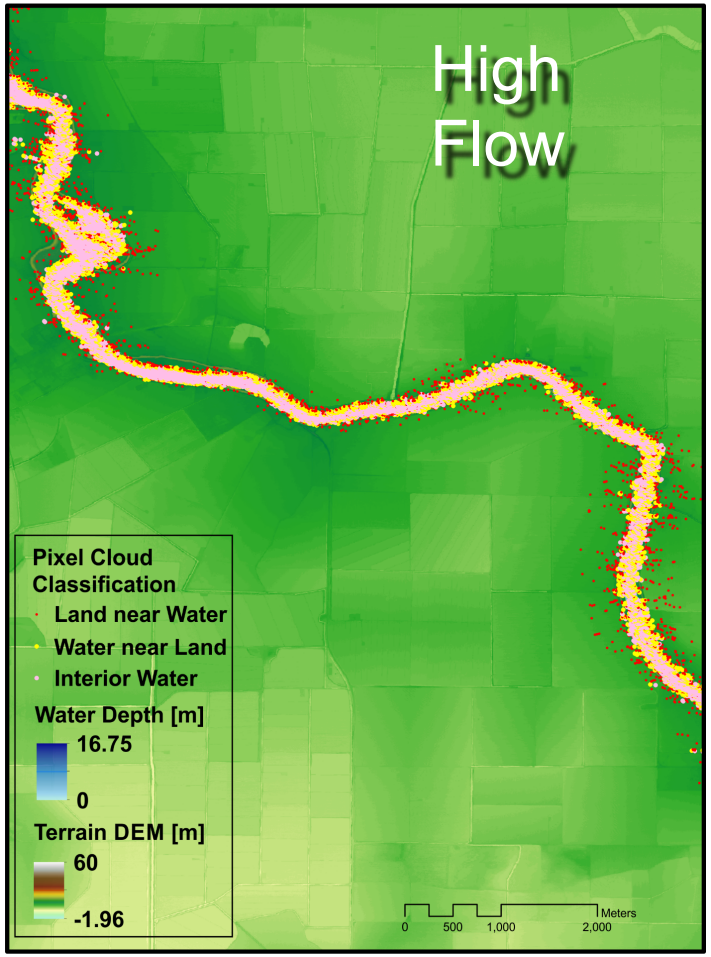
User Experience (OSU): Sacramento Simulation for Reach-Averaging Studies

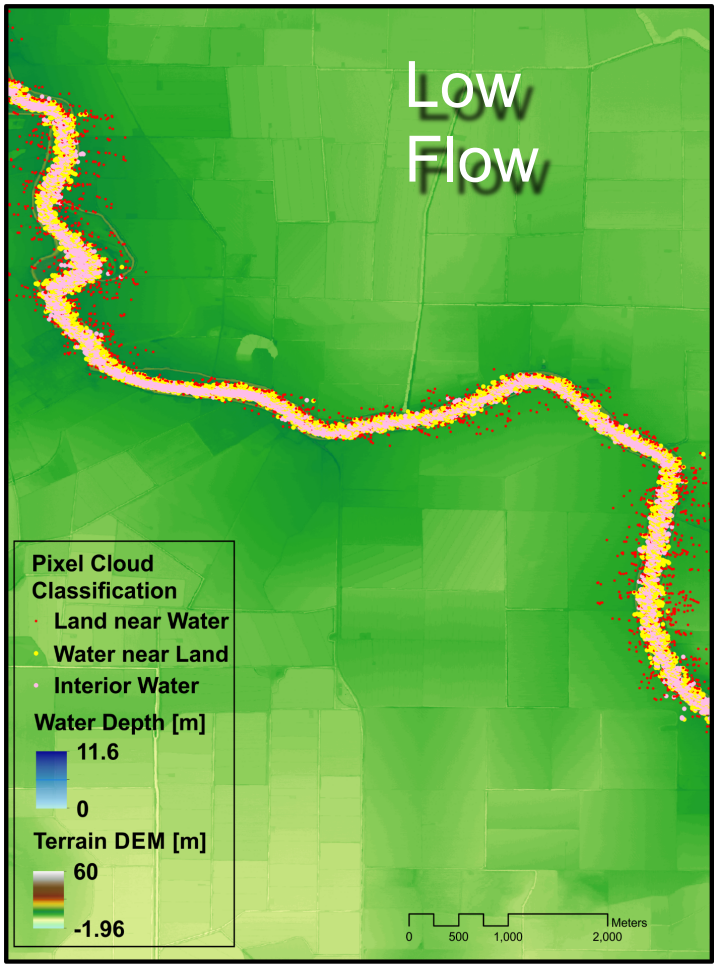


3-m LiDAR DEM, combined with HEC-RAS hydraulic model, provided by Toby Minear (USGS). Sacramento is ~100 m in width: low end for SWOT.

Six month dynamic instrument simulation performed, in order to study reach averaging dynamcis (see talk by R Frasson, Wednesday afternoon splinter)

User Experience (OSU): Sacramento Simulation for Reach-Averaging Studies

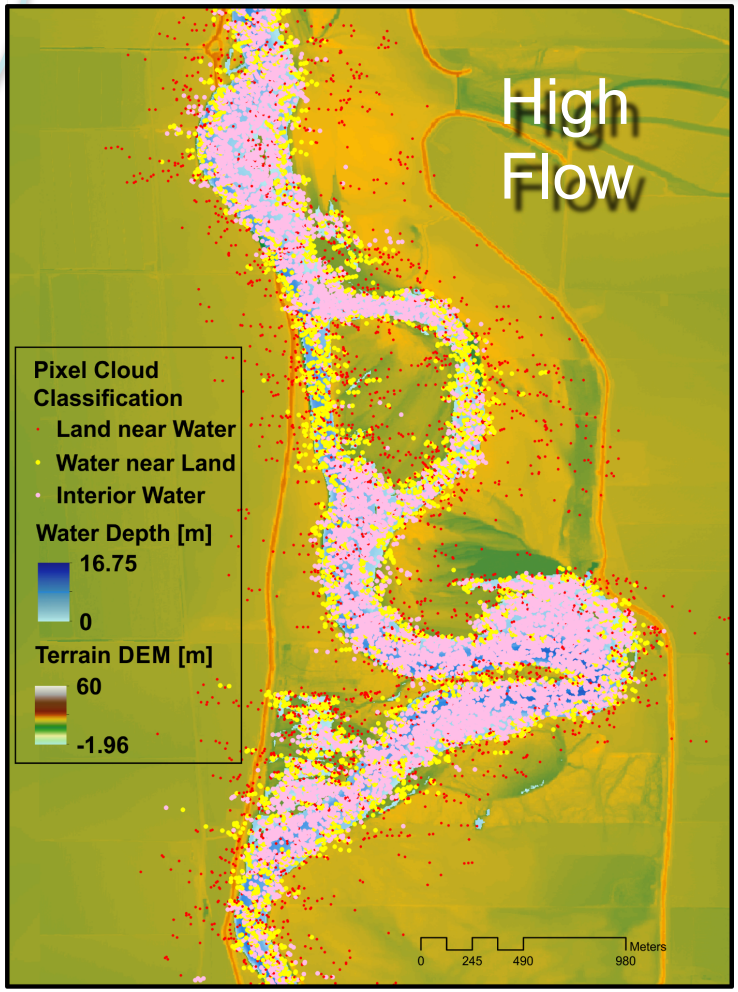


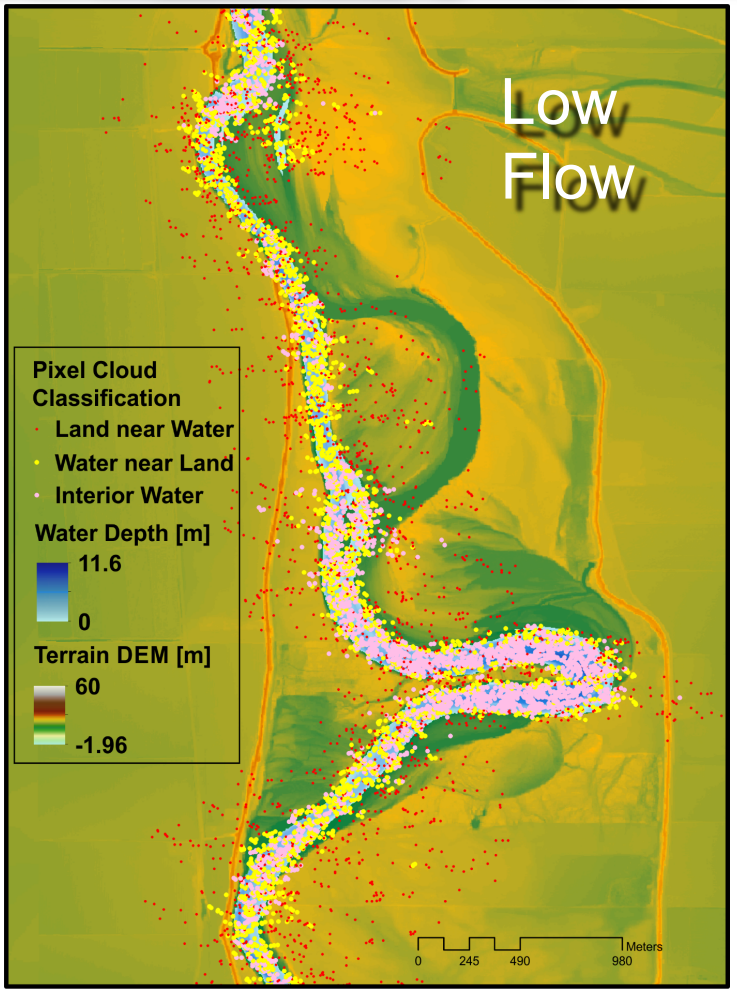


See poster by Rui Wei

Pixel cloud for straight and meandering sections downstream shows ability to resolve width changes at high flow

User Experience (OSU): Sacramento Simulation for Reach-Averaging Studies

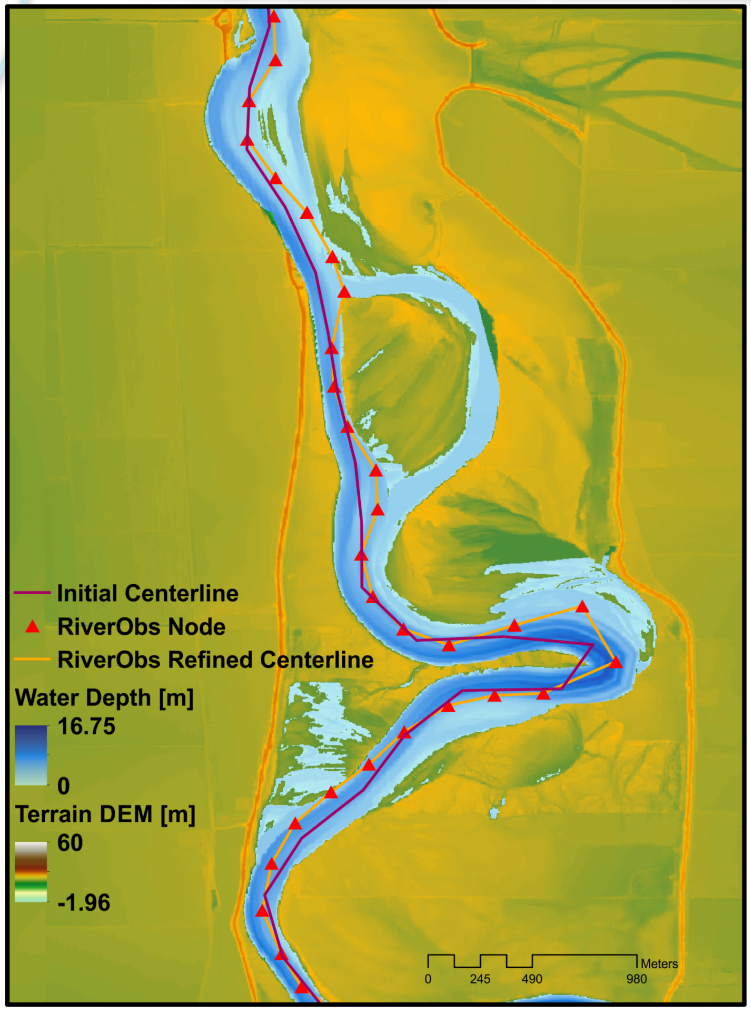


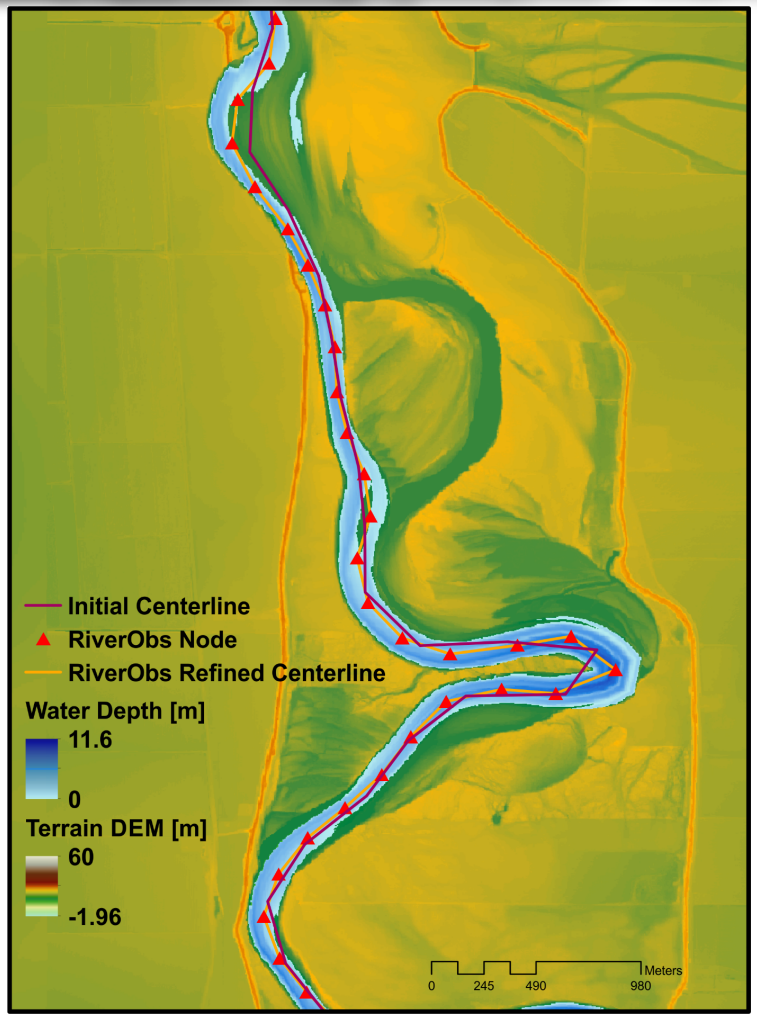


See poster by Rui Wei

For more complex reaches, pixel cloud is noisy but captures such features as occasional inundation of side channels, floodplain inundation

User Experience (OSU): Sacramento Simulation for Reach-Averaging Studies

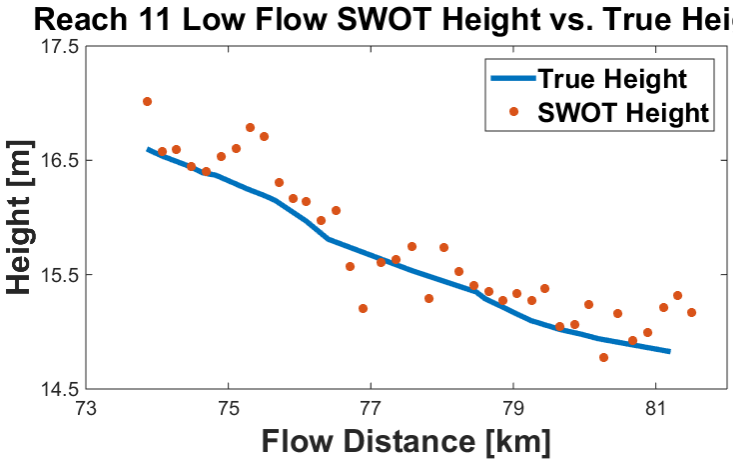


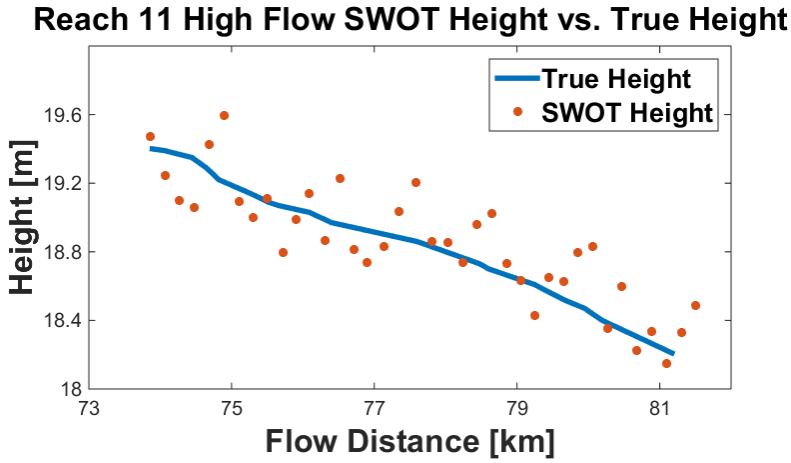


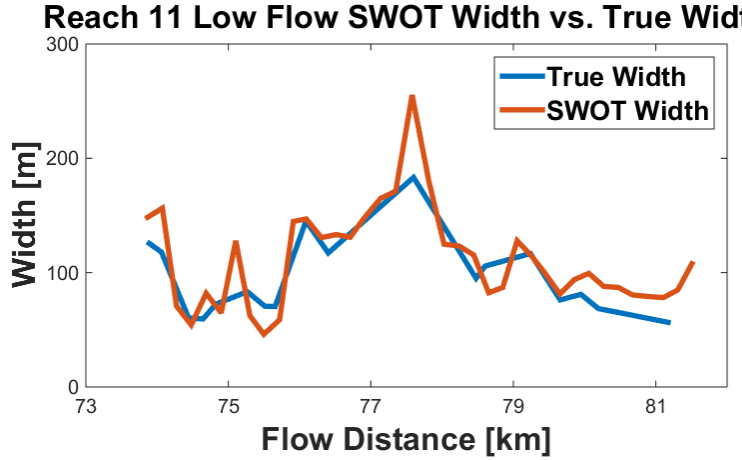
See poster by Rui Wei

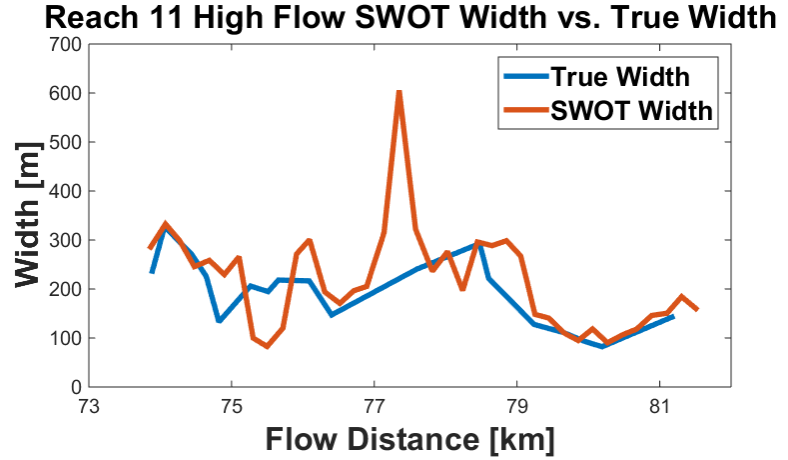
RiverObs used to calculate centerline from pixel cloud, compute heights and widths in 1-D river coordinate system at river nodes

User Experience (OSU): Sacramento Simulation for Reach-Averaging Studies







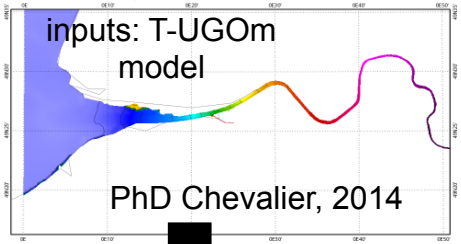


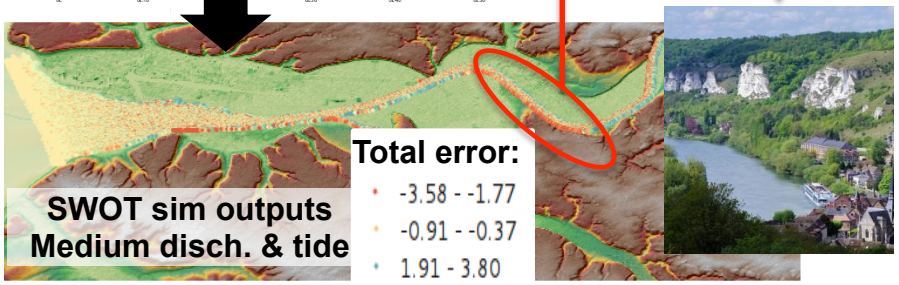
At node level, widths and heights are noisy, though show skill in some cases. Reach-averaged results discussed by Renato Frasson, in Wednesday splinter session.

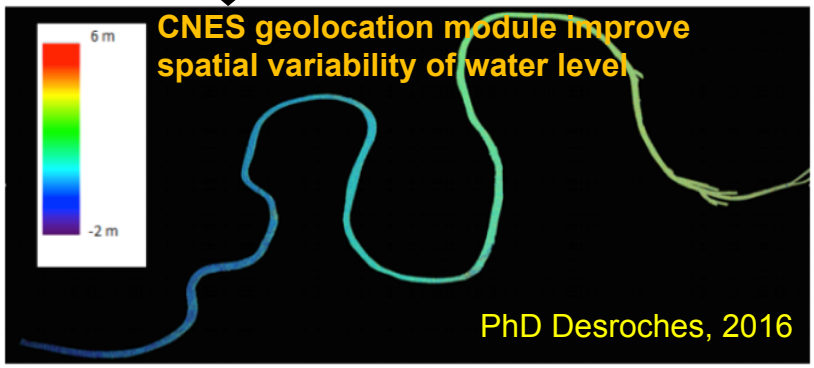
User Experience (FR): River & Estuary

Seine estuary

Chevalier L., Turki I., Laignel B. (M2C), Lyard F. (LEGOS), Blumstein D., D. Desroches D. Fjørtoft R. (CNES)



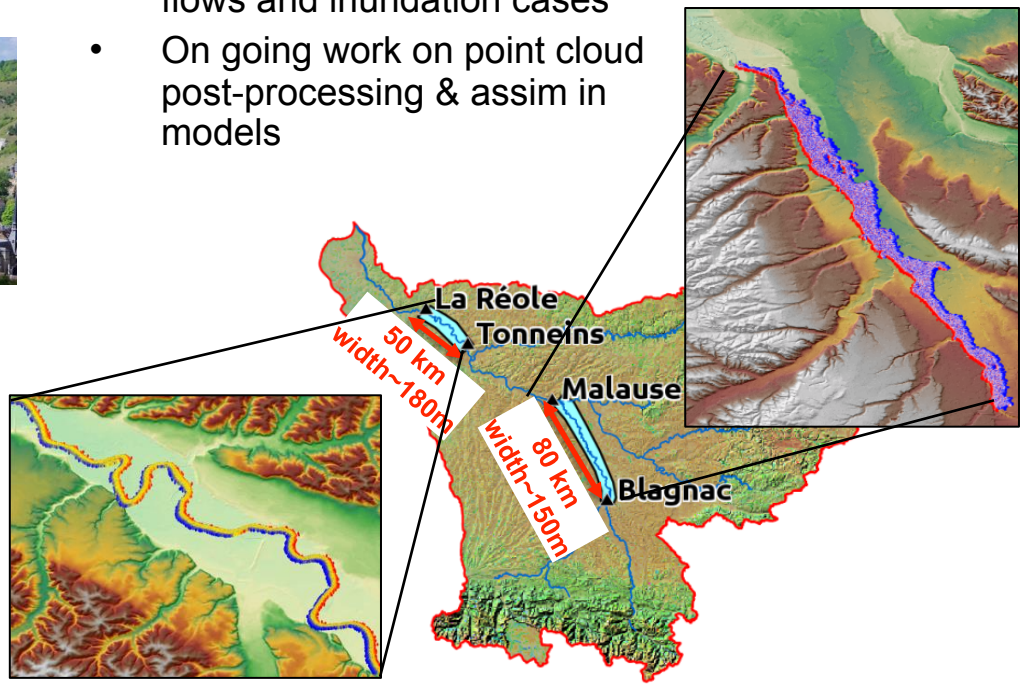




Garonne River

H. Roux, J. Chorda (IMFT) - J. Monnier, P. Brisset (IMT) - P.-A. Garambois (IMFS) - S. Ricci, A. Thévenin, N. Elmocayd (CERFACS) - N. Goutal (EDF/LNHE) – S. Biancamaria (LEGOS)

- SWOT sim for low, mean, high flows and inundation cases
- On going work on point cloud post-processing & assim in models

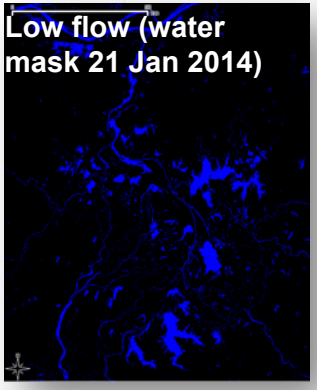


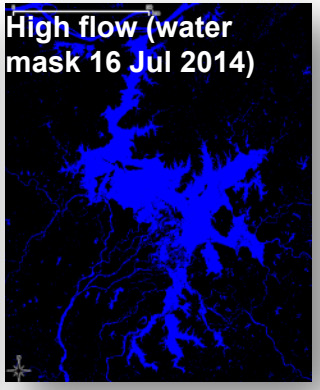
User Experience (FR): Lakes

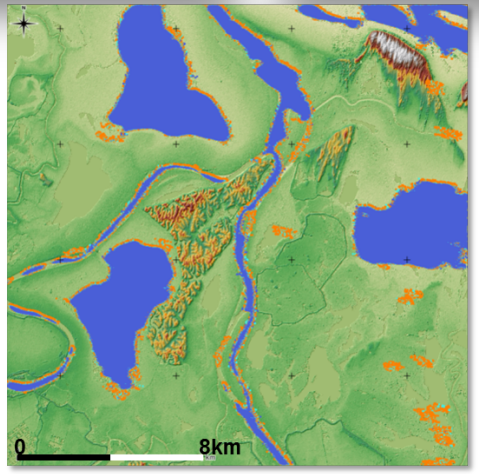
Yangtze & Poyang lake

L. Fruteau (LEGOS) - H. Yesou (SERTIT) – J.F. Crétaux, Calmant, D. Blumstein (LEGOS) – O. Thépaut (CS)

- Compute water budget over the Poyang Basin with SWOT simulated data + other sat. data







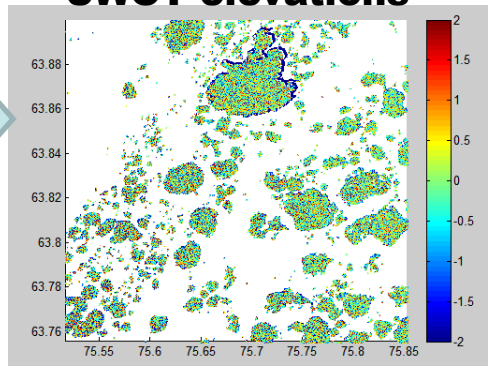
SWOT simu classification:
water Land near water

Arctic lakes

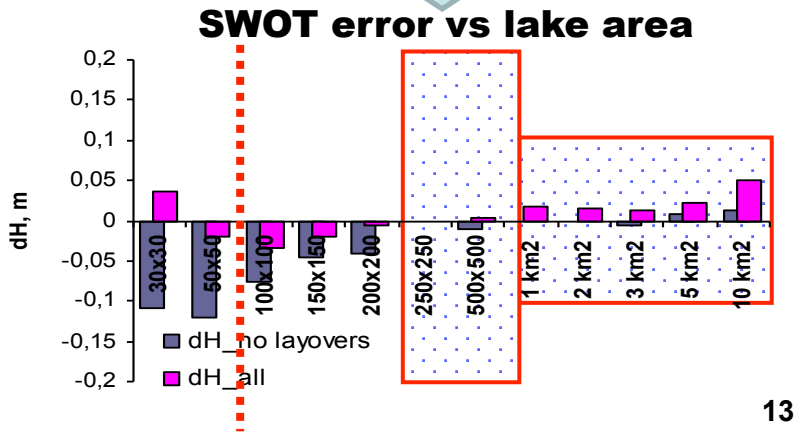
E. Zakharova, A. Kouraev, D. Blumstein, F. Remy (LEGOS)

- Compute water volume changes for multi lakes (west siberia in thawing permafrost region)
- Volume change between June & July (35% change in water area)

Simu Inputs :
• MNT GTOPO30 (corrected on water depth *Choulga et al., 2014*),
• water mask, water level



Mean err=-3 cm, std(dH) = 154 cm

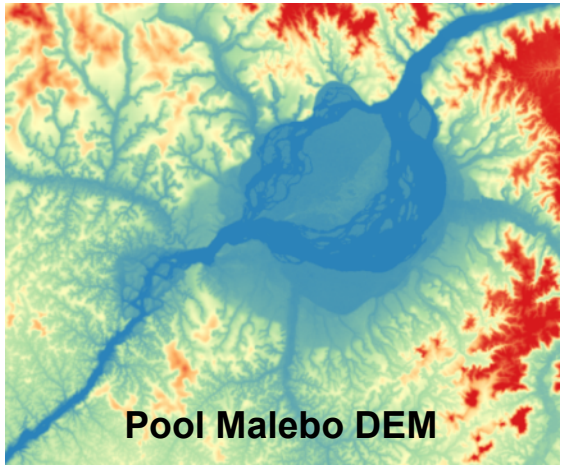


User Experience (FR): New Studies

Congo River: pool Malebo

L. Pothin, A. Andral (CNES)

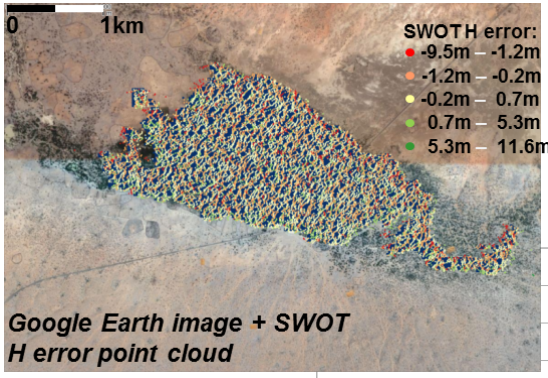
- Complex area: multi-tread channels (braided and anastomosing)
- Test potential vector products
- Impact of reach definition for mult channels
- Automatic detection of center line (to do)

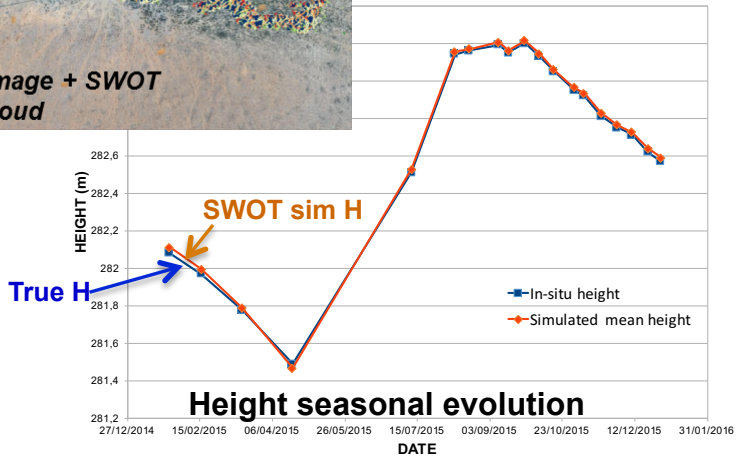


Agoufou pond (Sahel)

C. Rouzies, M. Grippa, L. Kergoat, L. Gal (GET)

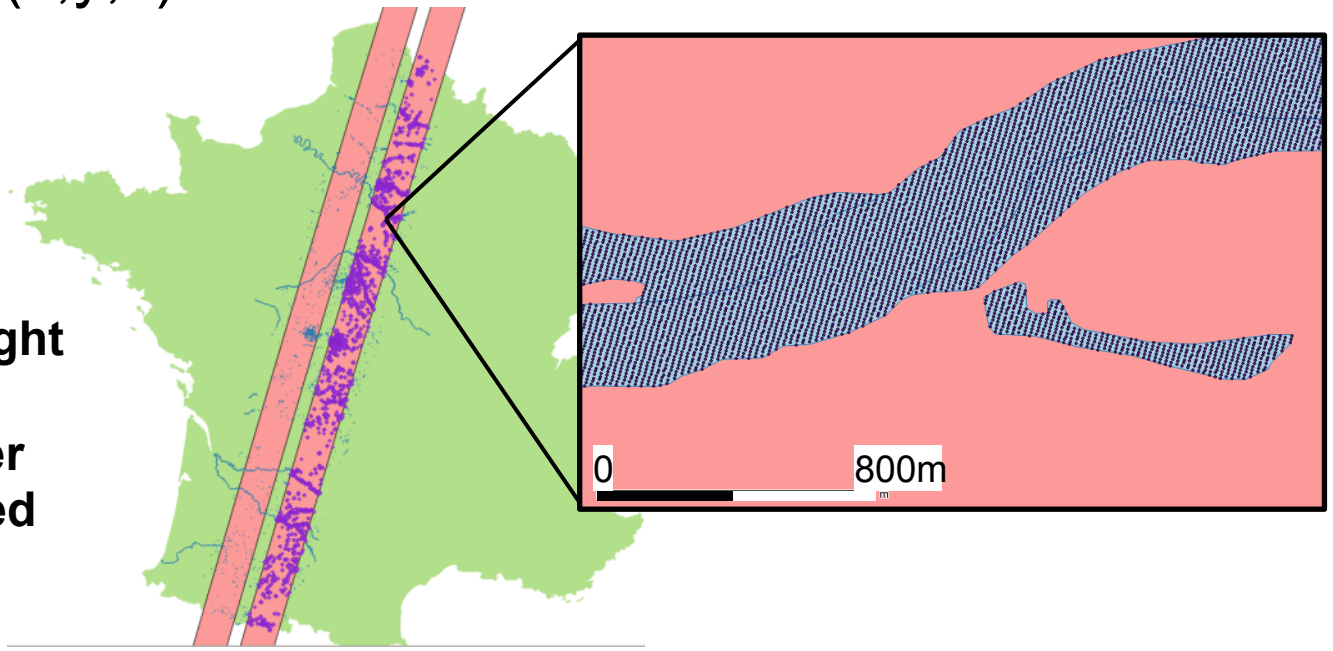
- Semi-arid climat, monsoon system, long dry season
- Sahelian hydrology poorly understood + societal impact





Large-scale SWOT Pixel-cloud Simulator

- A simplified tool currently underdevelopment at CNES/ LEGOS:
  - Aim: simulate easily and quickly point cloud over huge spatial and temporal domains
  - Swath radar grid intersected with water body polygons + very crude (x,y,z) errors



- **1,025,321 points on left swath**
- **888,444 points on right swath**

-> 2 Million points over 920 km track computed less than 1 minute!

Large-scale SWOT Pixel-cloud Simulator

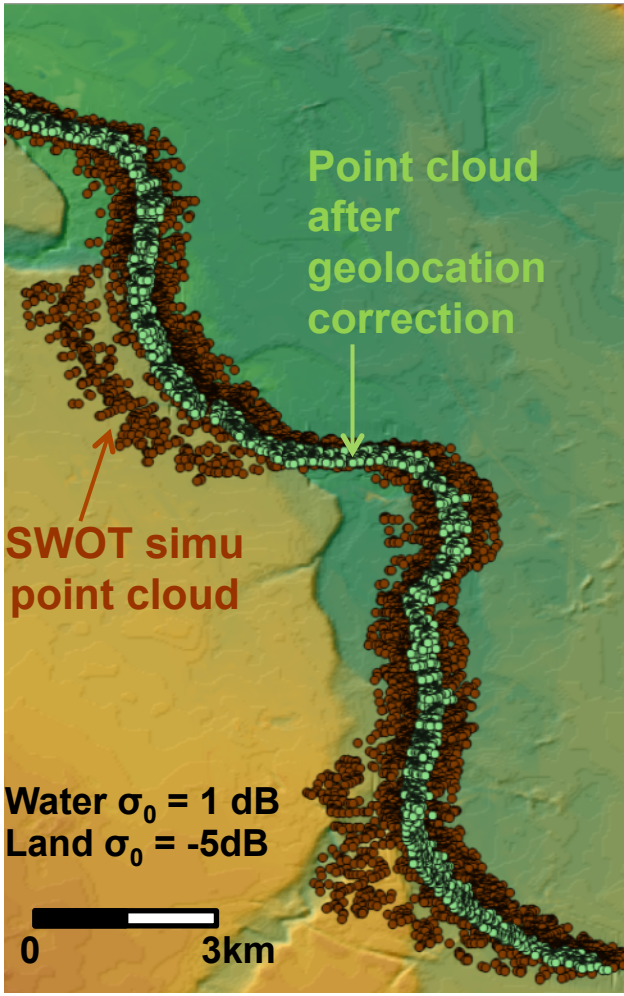
- Envisioned usages:
  - Generate and test potential hydro products + associated tools
  - Synthetic point clouds cases on huge domain for testing ground system processing chains.
  - Compute easily SWOT pseudo-obs for hydraulic/ hydrologic modeling at large scale (?)
- Errors:
  - Impact of radiometric noise on height and geolocation (x,y,z)
  - No accurate layover computed: could be added (statistically or other method…)

Summary

Ideal tool to add new modules to test ADT algorithms:

- Select orbit, interferogram, estimate height… (JPL)
- One water classification module already implemented (JPL)
- River reach vector product package RiverObs (JPL)
- Vegetation module (CNES/LEGOS): impact on interferogram
- Point cloud geolocation module (CNES/LEGOS): correct pt cloud (x,y) + height/slope reach average
- Impact of DEM 1st guess on phase unwrapping (for ADT, CNES)
- Water classification module (CNES)
- Realist attitude calibration error model (CLS/CNES)

- Modules available to ST scientists: help to validate ADT algo on different rivers/lakes, get more realistic SWOT data for scientists
- Stimulate feedback between project teams, ADT WG and ST scientists



Backup

SWOT Hydrology Simulator (JPL)

- Simulates data and processing from radar interferograms to the geolocated pixel cloud
- Distributed target simulator
  - Directly generates interferograms with appropriate statistics for SWOT geometry
- Implements
  - Interferogram generation considering
    - Presumming
    - Coherence-time azimuth smearing of water
    - Noise addition considering coherent gain power
  - Multilooking (simple and adaptive)
  - Water detection
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- Inputs needed
  - GDEM DEM=DEM with water mask
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- Update soon to be distributed with
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  - Algorithm improvements
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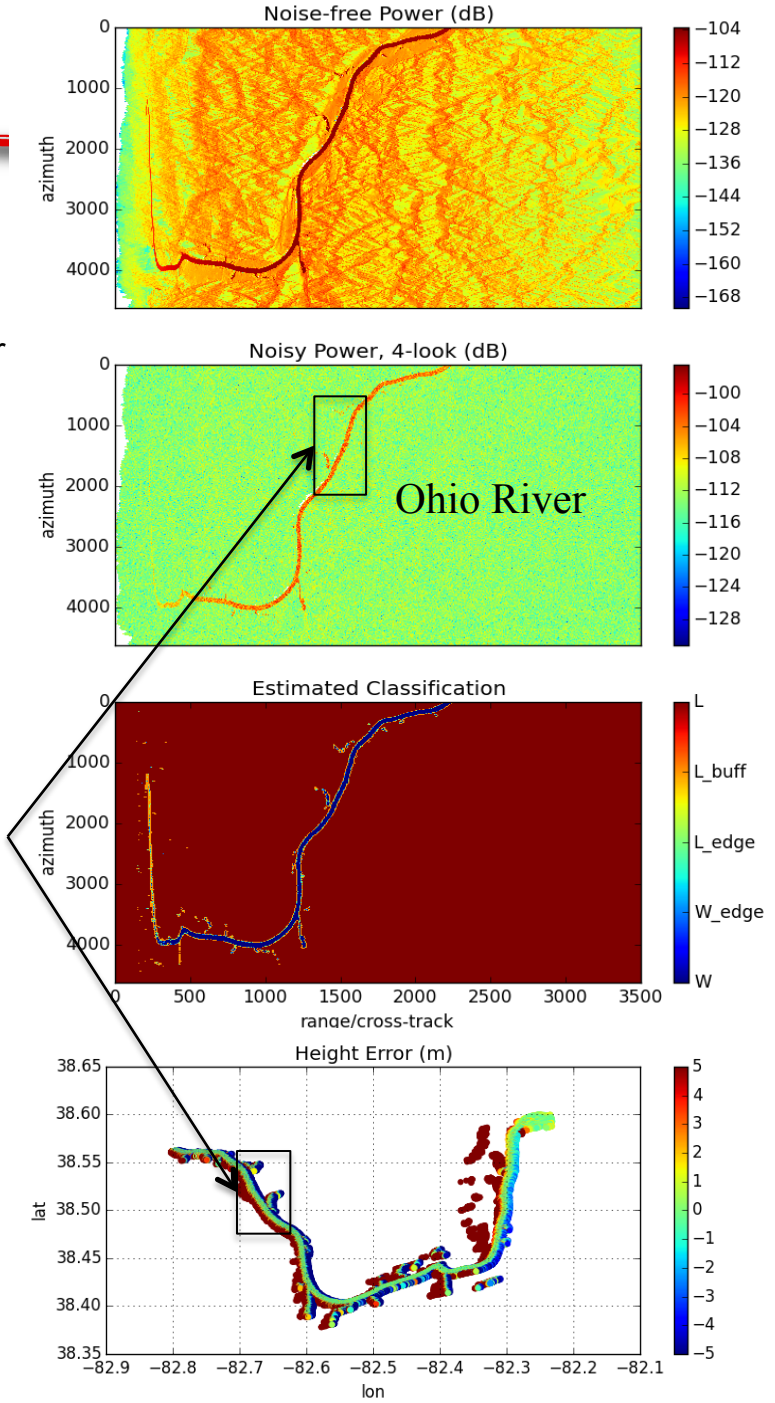
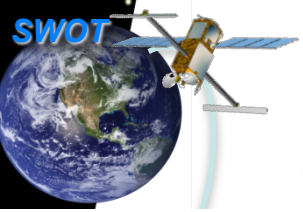
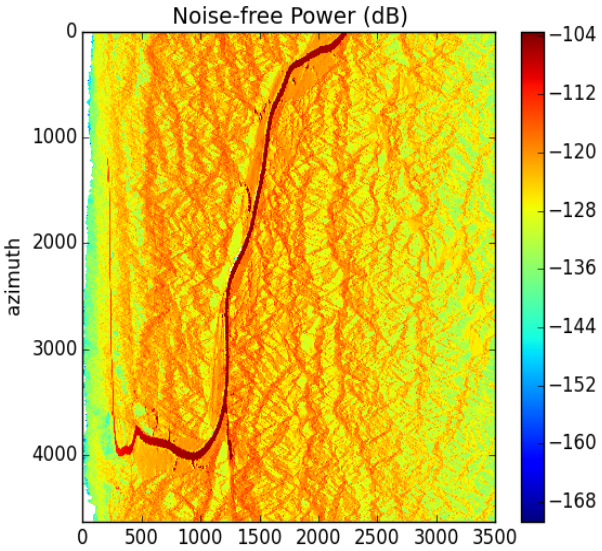
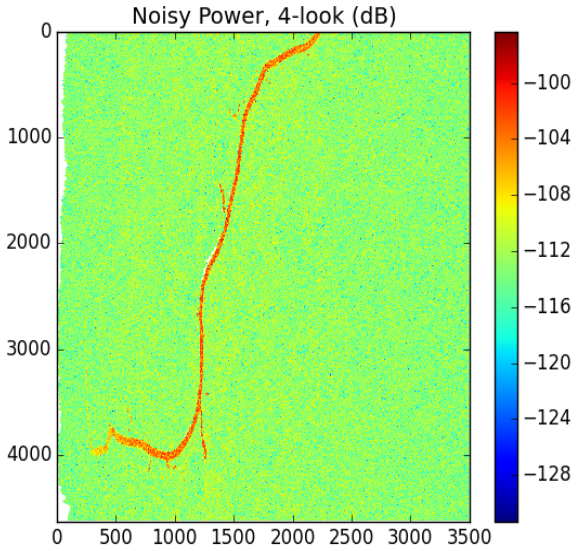
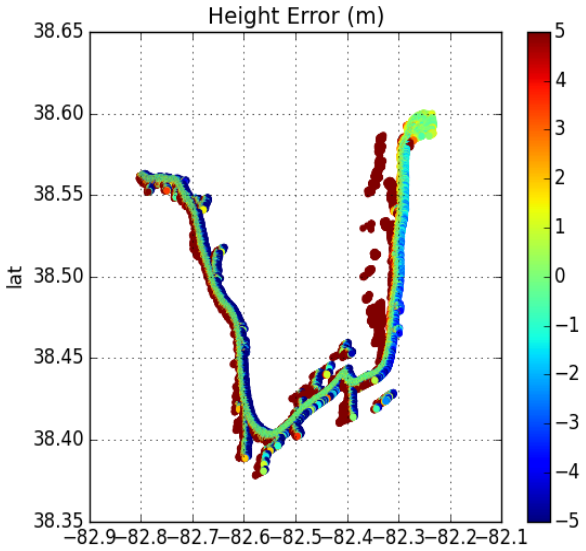


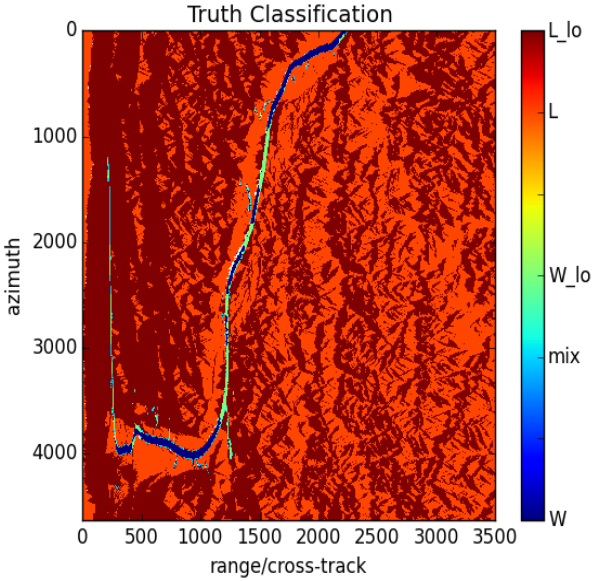
Ohio Example (Left Swath)

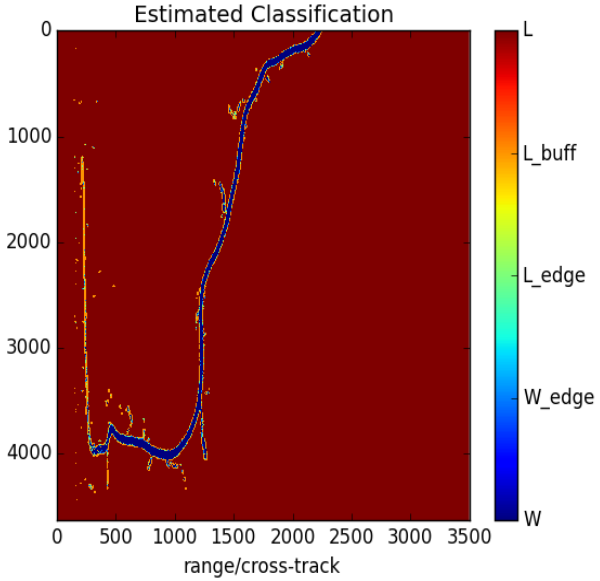


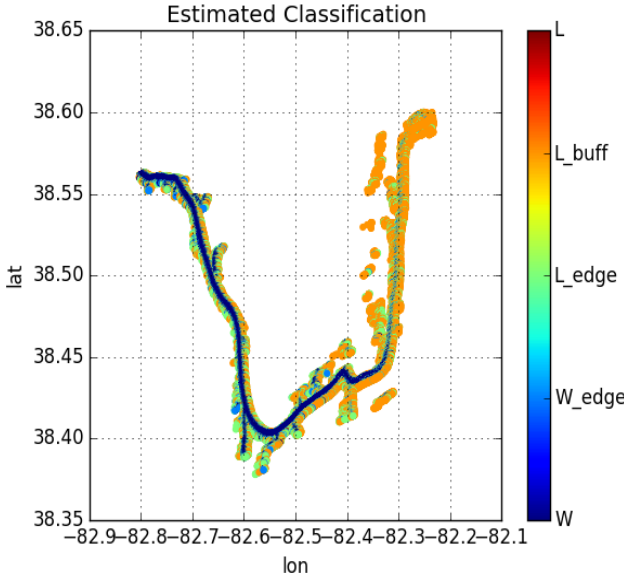












Ohio Example (Zoomed, Mid-swath)